

# A review on sensor spatial resolution & a proposal on grid pixel sizing

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## 0. Abstract

Sensor spatial resolution (SSR) is a determining factor in developing remote sensing instruments for earth observations. The SSR is defined as the full width at half maximum (FWHM) of sensor point/line spread function (PSF/LSF). This presentation first discusses large variations in image absolute SSR and SSR ratios to ground sampling distance (GSD) or grid pixel size from multiple instruments including AVHRR (Advanced Very-High-Resolution Radiometer), MODIS (Moderate Resolution Imaging Spectroradiometer), VIIRS (Visible Infrared Imaging Radiometer Suite), WorldView and Planet. When the physics-based SSR is more than twice the nominal grid pixel size, a more appropriate grid pixel size is proposed.

## 1. Introduction

### Categories of spatial resolutions

The (draft) Guidelines define:

- LR: Low Resolution (spatial resolution > 300 m).  
MR: Medium Resolution (300 m > spatial resolution > 30 m).  
HR: High Resolution (30 m > spatial resolution > 5 m).  
VHR: Very High Resolution (spatial resolution < 5 m).

### Definitions of spatial resolutions

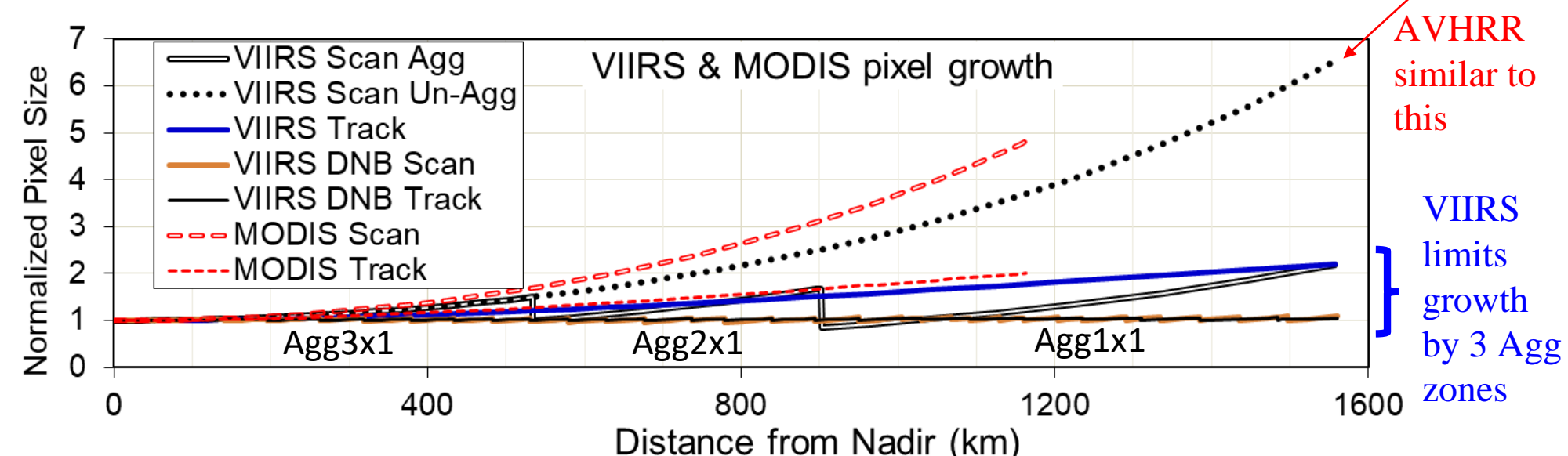
- Ground sampling distance (GSD): separation between centers of two adjacent samples on the ground, varies off-nadir.
- Sensor Spatial Resolution (SSR): full-width at half-maximum (FWHM) of sensor line spread function (LSF) projected on the ground, varies off-nadir.
- Gridded image pixel resolution: evenly distributed grid cells in a map projection. The size is vendor defined, may not be based on physics.**



Earth Observation Mission Quality  
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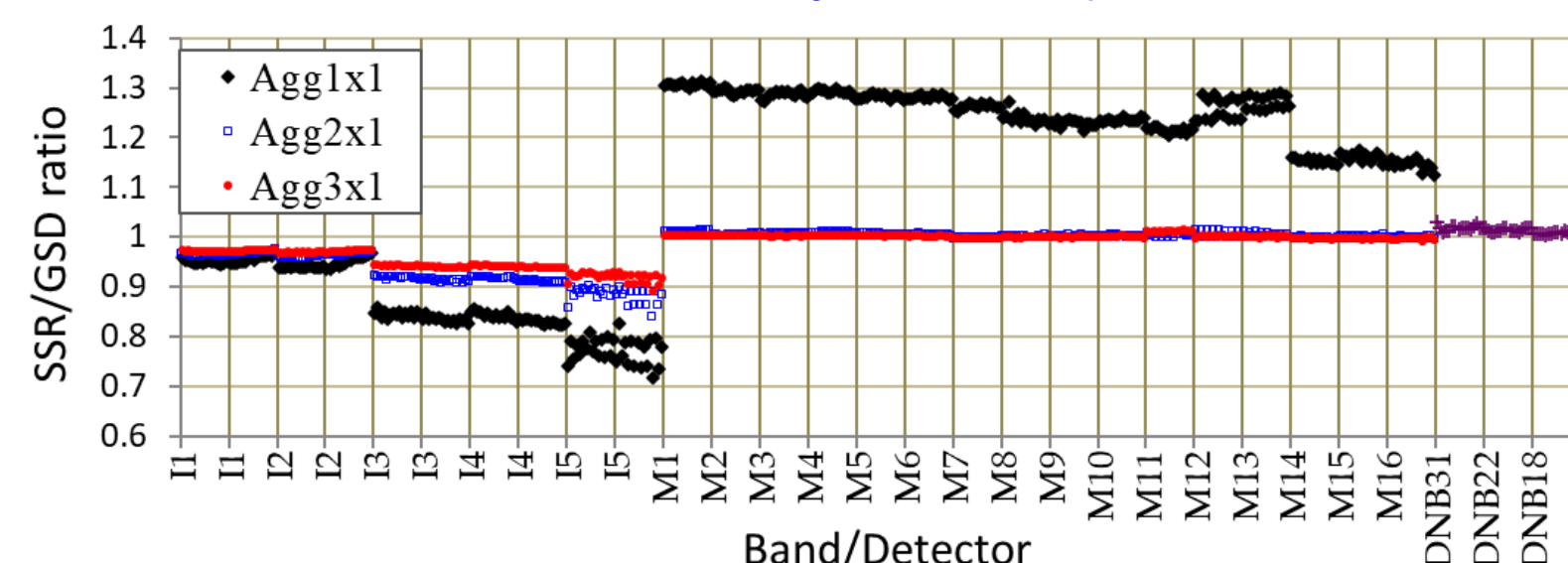
## 2. Example LR and MR sensor GSD and SSR

### GSD for AVHRR, MODIS, and VIIRS



- MODIS has 3 resolutions: 250 m, 500 m, 1 km at nadir.
- VIIRS has 3 resolutions: 375 m, 750 m at nadir, & DNB 750 m scan-wise. Dual gain M-bands have un-aggregated resolution 250 m at nadir, grows 6 times towards the edges.
- AVHRR resolution 1.1 km at nadir, growth similar to VIIRS un-aggregated bands.

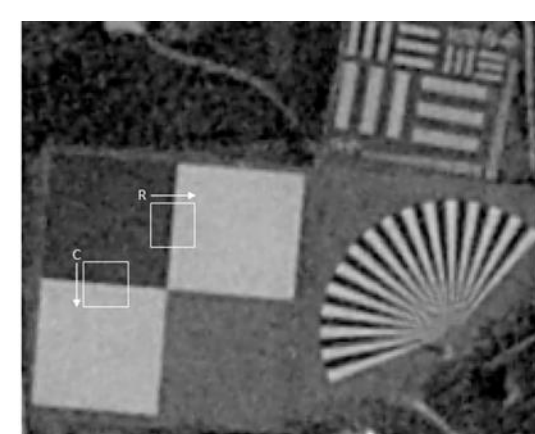
### Suomi-NPP VIIRS scan direction SSR/GSD ratio, serves as a reference



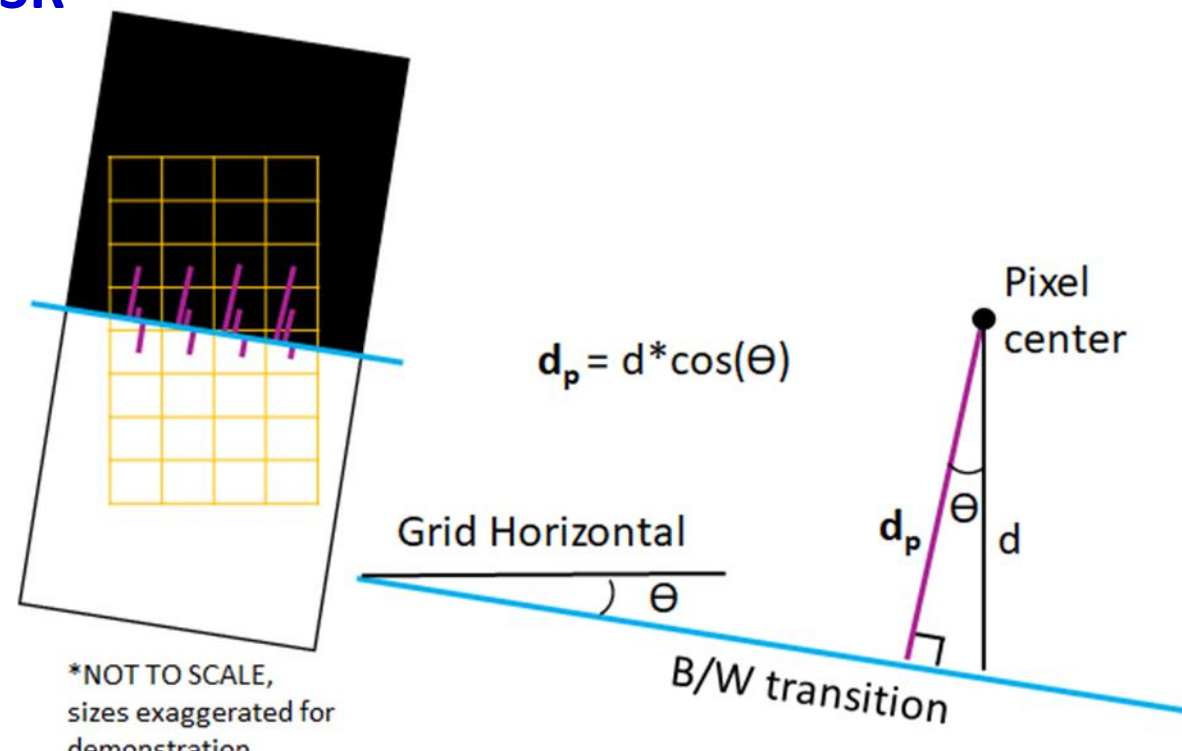
- I-bands under-sample in all aggregation zones in the scan direction.
- M-bands over-sample in Agg1x1 zones in the scan direction.
- DNB and M-bands in Agg2x1 & 3x1 zones sample at Nyquist frequency.
- All bands have nearly square LSFs in the track direction, SSR = GSD.

## 3. SSR estimates for VHR images

### Method of estimating SSR

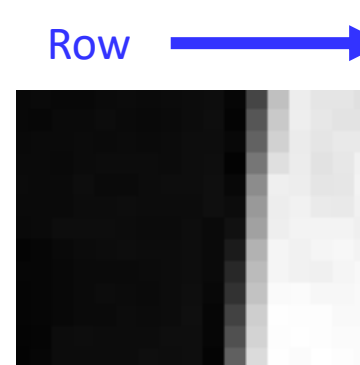


<https://calval.cr.usgs.gov/apps/baotou>



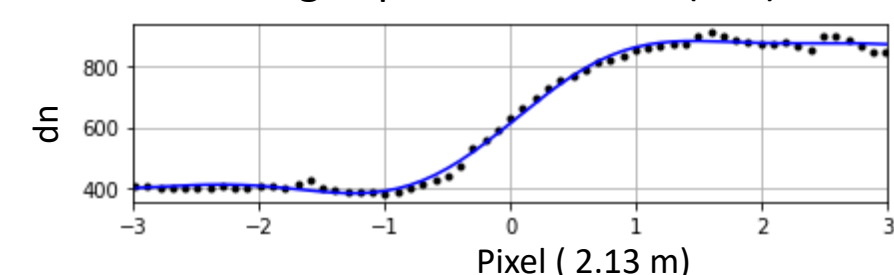
Spatial resolution CalVal site in Baotou, China. The site is at 40.854°N, 109.628°E. It has 48 m x 48 m black/white squares, slanted at 5°. Gridded VHR images over the site can be used to construct edge spread functions (ESFs), which → line spread functions (LSFs) → SSR (FWHM). All assessments are performed with the red band in row direction for **demonstration** here.

### SSR (FWHM) estimates for WorldView and PlanetScope images

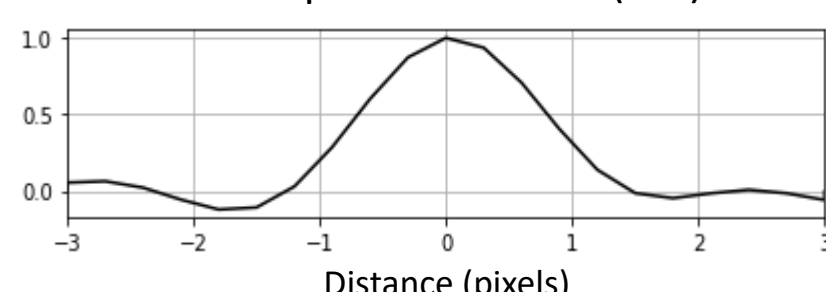


Worldview-2 image, red band raw pixels: along row

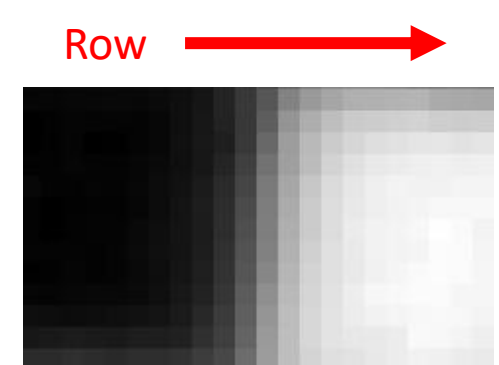
Edge Spread Function (ESF)



Line Spread Function (LSF)

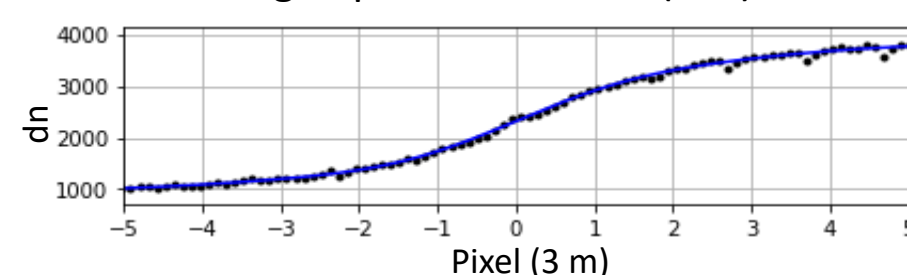


FWHM = 1.5 pixels = 3.2 m

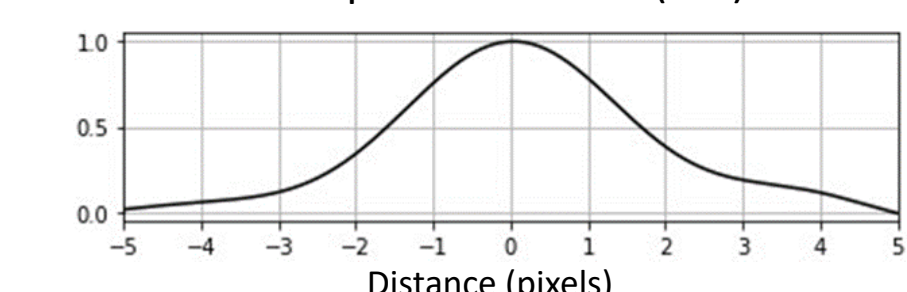


Planet Image, red band raw pixels: along row

Edge Spread Function (ESF)



Line Spread Function (LSF)



FWHM = 3.3 pixels = 9.9 m

- Slower edge transition blurs the edge. It has larger SSR/pixel ratio.
- The Planet image is over-sampled 3 times.

## 4. A proposal for gridded image pixel size

### Comparing original, aggregated PlanetScope images

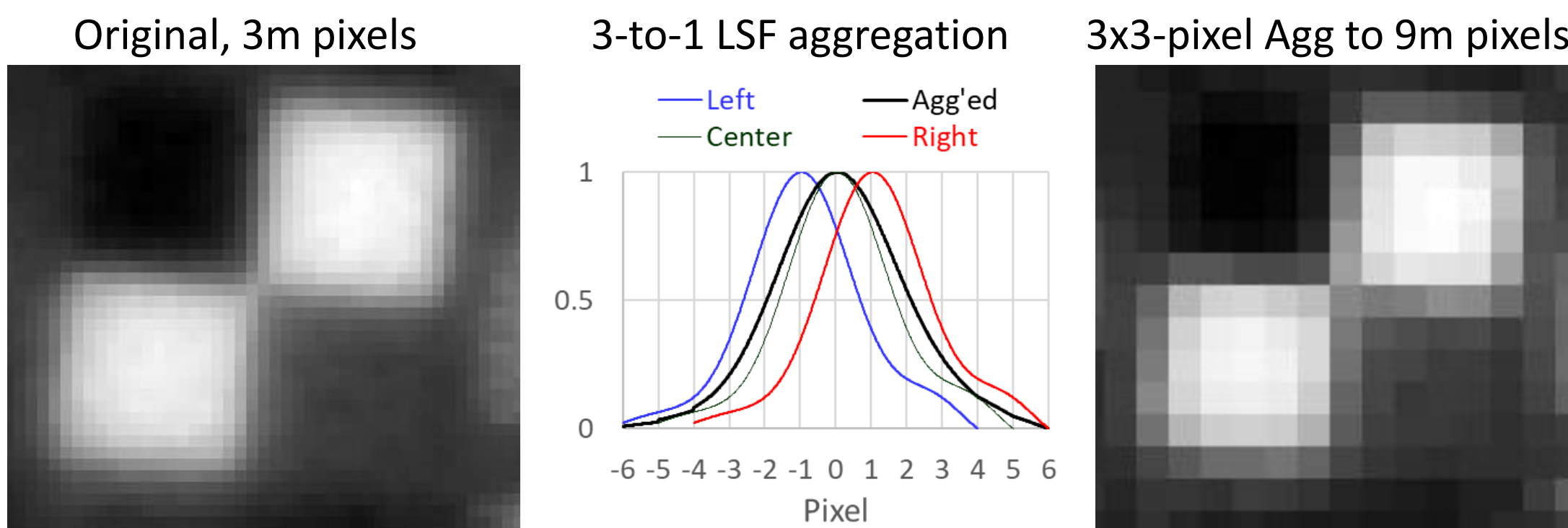


Image ID: 20221005\_031939\_43\_2254  
SSR/pixel-size ratio = 3.3

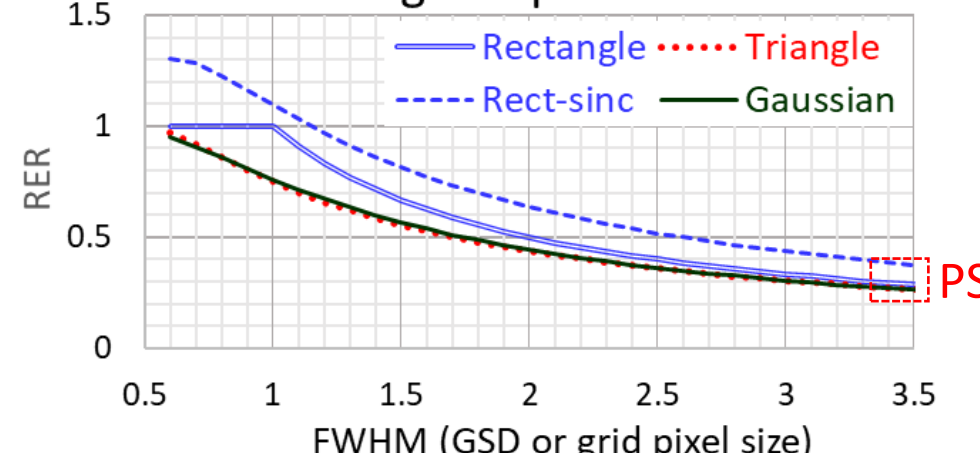
Agg'ed FWHM = 4.1 pixels  
= 1.4 agg'ed pixels

SSR/pixel-size ratio = 1.4

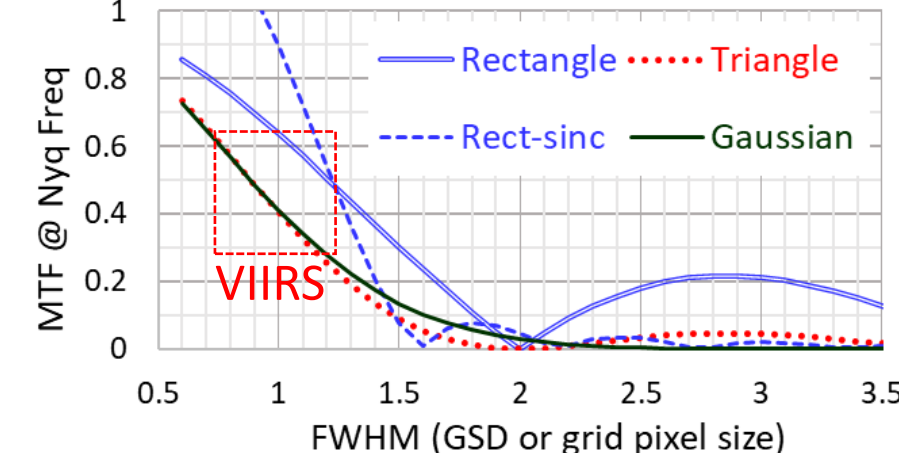
- The aggregated image has sharper edges, reducing SSR/pixel-size ratio from 3.3 to 1.4
- It saves ~90% compressed volume (1.11 GB:114.5 MB) and increases SNR 200%.

### Future work: set better standards/requirements in SSR, RER and/or MTF

#### Relative edge response vs FWHM



#### MTF @ Nyquist freq vs FWHM



- 4 forms of LSFs are simulated; sinc function is "rectified" to  $[-2\pi, +2\pi]$
- Set  $SSR(FWHM) < 1.5$  grid-pixel-size,  $RER > 0.6$ , and/or  $MTF@NyquistFreq > 0.2$ ?

## 5. Concluding remarks

The physics-based SSR (sensor spatial resolution) is defined by the full width at half maximum (FWHM) of sensor line spread function (LSF). When  $SSR >$  gridded image pixel size, over-sampling occurs. When the  $SSR/pixel\text{-}size\text{ ratio} > 2$ , aggregation may be performed to reduce data volume and to increase SNR (signal noise ratio). We propose to keep gridded pixel size as close to SSR as possible.